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THE ANATOMY AND PHYSIOLOGY OF THE SHOEMAKER. By W. ARBUTHNOT LANE, M.S., *Assistant Surgeon to Guy's Hospital, and to the Hospital for Sick Children, Great Ormond Street.* (PLATE XIX.)

THE body—the changes in whose anatomy forms the subject of this paper—was sent to the hospital for dissection. I was therefore enabled to observe accurately every structural variation that had resulted from the habitual performance of a definite series of movements, entailing the expenditure of a considerable amount of muscular energy during the greater part of a long lifetime of seventy-three years.

Having concluded, from a careful examination of the changes which the body presented, that the man had been a shoemaker, I wrote to the medical officer of the infirmary in which he died for any information he could give me, and he kindly informed me that the man was entered on the books as a shoemaker.

An occupation such as this is one which, when the person engaged in it is in very indigent circumstances, is carried on without variation during the whole adult lifetime of the individual, and is not, as in many kinds of labour, relinquished of necessity as old age approaches for others which are less laborious. I believe that it is by the careful observation of the changes in form and structure which bones, joints, and muscles undergo, when exposed to the influence of a series of definite movements, that we shall obtain an accurate insight into the various factors that determine not only the variations in the character of these structures in individuals of the same race, but also in members of the different races of man and of the quadrumana, together with the manner in which the factors evolved by an alteration in habits, resulting from a change in the surroundings, experience, &c., of the individual, caused alterations in the shapes of the bones, &c., and so produced new types.

I would therefore make no apology for describing most minutely the deviations from the normal type which the skeleton of this man presented, were it not that I feel such a description would prove very tedious to my readers. On that account I have rendered the descriptions of the anatomical conditions *as brief as possible,* though I trust not too brief to be intelligible. In considering these changes, I will proceed in a manner the reverse of that which I was obliged to pursue in examining the body, since I was at that time uncertain as to the man's occupation. The reader is probably familiar with the manner in which shoemakers perform their work, so that I need hardly describe its details. I will select the most important function, namely, the process of hand-sewing. Other portions of their work are laborious, but they are not of a character to produce much structural alteration. In sewing the boot the last is fixed firmly between the front of the chest and the upper aspect of the thigh, and the awl is used for making holes, through which the waxed threads are passed and then pulled tight. This pressure produced a marked alteration in the form of the thorax, which was so extreme that one would suppose that it must have been noticed through his clothes during lifetime.

On removing the skin and soft parts from the front of the chest, the lower portion of the sternum was found to form the floor of a deep concavity, below which there was on each side a large prominence, produced by the eversion and projection forwards of the sixth, seventh, eighth, and ninth costal cartilages.

The anterior surface of the gladiolus, and especially of its lower half, was covered by *a thick layer of dense fibrous tissue.* This was evidently produced by the blending of the *enormously hypertrophied anterior chondro-sternal ligaments* with those immediately adjacent on the same side, and with their fellows across the middle line. On cutting through this fibrous layer a subjacent layer of soft vascular tissue was exposed.

Crossing transversely, the front of the manubrio-gladiolar articulation was a similar, though separate, hypertrophy of the second anterior chondro-sternal ligaments.

On removing this there was exposed in the middle line a *vertical anterior manubrio-gladiolar ligament* of considerable strength, and possessing apparently but little elasticity. It was half an inch in breadth, and its margins were thick and well defined. It was attached above to the front of the manubrium, immediately above its lower limit, and below to a corresponding portion of the gladiolus. It crossed the centre of the manubrio-gladiolar articulation, and its fibres were rendered very tense when pressure was exerted upon the anterior surface of the gladiolus.

The *manubrio-gladiolar articulation* was very broad. It permitted of no rotation of the manubrium around its antero-posterior axis upon the gladiolus, the articulation having been apparently converted into a *hinge-joint*, the manubrium and gladiolus moving upon one another only around a transverse axis, which passed through the joint connecting them.

The concavity formed by the anterior surface of the lower portion of the gladiolus occupied a vertical plane 2¾ inches behind that in which the extremities of the projections formed by the seventh, eighth, and ninth costal cartilages lay.

The xiphoid cartilage was completely ossified, and was connected by bone to the gladiolus. It was curved in such a manner that it prolonged the plane of the concavity of the anterior surface of the gladiolus, and its lower extremity was tilted forwards. It was narrow, but thick and strong, and on transverse section it was found to be triangular, the base of the triangle being directed forwards.

While the trunk rested in a supine position upon the table, the posterior sharp angle of the ossified xiphoid cartilage was separated from the front of the spinal column by an interval of 1½ inches, but when the body was placed in the sedentary attitude, the sharp posterior margin of this portion of the sternum was separated by a small interval of but ¾ inch from the spine. This small interval was occupied by the liver, diaphragm, and aorta, all of which appeared to be considerably compressed.

The second to the seventh costal cartilages presented very abundant osseous change, which increased in amount from above downwards, and was more extensive on the left side than on the right.

In the normal human subject the manubrio-gladiolar articulation performs two distinct functions, one of which is to permit of the rotation of the manubrium and first and second costal arches around an antero-posterior axis upon the gladiolus; the other is to allow of the gladiolus moving upon the manubrium around a transverse axis passing through the manubrio-gladiolar articulation. The manner in which this articulation is developed, the necessity for its existence, and the factors determining its evolution, I have discussed fully in previous papers.[1]

Now, in the shoemaker, the gladiolus sustained upon its anterior surface habitually an enormous amount of pressure. This resulted partly in the local change which this bone and the cartilages connected with it had undergone. It also produced an extreme flexion of the manubrio-gladiolar articulation, and rotated the manubrium very forcibly around a transverse axis passing through it. Owing to its very intimate attachment to the manubrium, the first costal arch sustained a very great strain, which tended to twist the first costal cartilages around an axis passing through their length, and to displace the heads and tuberosities of the first ribs upwards from their articulations with the body and transverse processes of the first dorsal vertebræ.

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[1] "The Causation of some of the so-called Congenital Abnormalities and Variations," *Journal of Anatomy and Physiology*, 1887, &c.

In consequence of the habitual presence of these powerful tendencies to the production of excessive movement, and with the evident object of opposing and limiting, the following very remarkable conditions resulted :—

The manubrio-gladiolar joint assumed the character of a hinge-joint, and permitted of movement of the gladiolus upon the manubrium only around a transverse axis, and in order to limit excessive flexion of these bones upon one another a very powerful anterior manubrio-gladiolar ligament was developed.

The strain sustained by the first costal cartilages resulted in their very complete ossification, and though it was necessary that some joint should develop in the rigid cartilage, yet this joint was placed very obliquely, its outline was remarkably irregular, and the movements permitted in it were very limited. By the prolongation of its opposing articular surfaces downwards and inwards in an irregular manner, the movement of the manubrium around a transverse axis was still further limited, and resisted as much as possible. The habitual tendency to the upward displacement of the head and tubercles of the first ribs resulted in the considerable increase in the thickness of these ribs, in the strengthening of the costo-transverse articulations, and in the formation of cup-shaped cavities for the heads of the first ribs, similar in character to those I found in the coal-trimmer,[1] in which the tendency to upward displacement of the heads of the first ribs, which determined the development of the cup-shaped articular cavities, resulted almost entirely from the functions performed by the shoulder girdles.

The pressure sustained by the front of the chest, besides producing a change in the form of the sternum, produced a remarkable limitation of movement in the costo-vertebral articulations. This was most marked in the case of the sixth ribs, which were anchylosed to the bodies and transverse processes of the vertebræ, with which they originally articulated. It was also sufficient to limit very considerably, if not to prevent completely, any movement of the upper half or more of the chest during respiration. It would appear that, under these circumstances, the diaphragm performed nearly the whole of the function of filling the lungs with air; in fact, respiration was then purely diaphragmatic.

The proportion which is normally borne by the muscular and tendinous constituents of the diaphragm to one another was materially altered in this subject. The muscular portion was remarkably thick, and encroached very considerably upon the area which is normally tendinous. Thick bundles of muscle fibre projected prominently from the under surface of the muscular layer.

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[1] "A Remarkable Instance of the manner in which Pressure-Changes may enable us to determine the Labour-History of the Individual," *Journal of Anatomy and Physiology*, 1887.

The pressure sustained by the soft structures which intervened between the xiphoid cartilage and spinal column resulted in much change in their form and relative positions to one another, and to the thoracic parietes.

The liver was displaced downwards by the apposition of the anterior and posterior walls of the chest, the pressure exerted by the xiphoid cartilage having severed almost completely the right from the left lobe of the liver. The left lobe, so separated, bore an abnormally small relation to the right.

The separation of the upper concavity into two separate domes caused the right lobe of the liver to be crushed up laterally into the right one, this compression resulting in the formation of the three antero-posterior grooves upon its upper surface. *The obvious mode of production of the fissures in this liver proves that fissures in the liver can be produced by pressure acting upon it either directly or indirectly.* It seemed that the nipping of the liver and other soft structures between the xiphoid cartilage and spinal column rendered the arch of the diaphragm very tense in the middle line, and by pulling upwards upon the conjoined crura it diminished the calibre of the orifice for the aorta, and so constricted this vessel at this point, and produced the dilatation of the thoracic aorta.

Or it is possible that the pressure which the third piece of the sternum exerted upon the diaphragm, where it covered the lower portion of the thoracic aorta, might have rendered the aortic orifice more oblique and its antero-posterior diameter correspondingly less. That the resistance which was offered at this point to the passage of blood was considerable was shown by the considerable and abrupt diminution in the calibre of the vessel, though no branch had arisen between the points at which it was measured, and by the abrupt line presented by the atheromatous change in the walls of the artery.

On removing the diaphragm and front of the chest, and exposing the aorta, that vessel was seen to be abruptly dilated above the aortic orifice in the diaphragm. Although no large branch came off between the points measured, the diameter of the lower extremity of the thoracic aorta was $1\frac{3}{16}$ inches, and that of the upper extremity of the abdominal aorta $\frac{15}{16}$ inch, the diameter of the thoracic aorta showing an excess of $\frac{1}{4}$ inch. The position of the margin of the aortic orifice in the diaphragm was indicated upon the aorta by an abrupt transition from an opaque white colour, which was presented by the lower $2\frac{1}{2}$ inches of the thoracic aorta, to the colour presented by the abdominal aorta, which appeared to be quite normal. The opacity of the coat of the thoracic aorta blended less abruptly above with the upper portion of the thoracic aorta, whose colour resembled that of the abdominal aorta and other large vessels.

The cœliac axis came off from the left portion of the anterior aspect of the thoracic aorta nearly $\frac{3}{4}$ inch above the aortic ring, and it passed with the aorta through the same aperture in the diaphragm. A calcareous atheromatous plate in the wall of the aorta surrounded the orifice of the cœliac axis, and that vessel itself appeared to be dilated, while its walls were opaque and atheromatous. The branches of the cœliac axis below the diaphragm were apparently quite normal.

On placing the body in the sedentary posture it was observed that the convex sharp margin of the xiphoid cartilage pressed upon the opaque portion of the thoracic aorta.

On opening this vessel the inner coats of its lower portion presented a considerable amount of atheromatous change, which was most marked in and about the origin of the cœliac axis. Similar, though less marked, degenerative changes were present in the abdominal aorta.

The upper portion of the thoracic aorta showed very slight atheromatous deposit.

The heart was not large. There was a considerable amount of fat surrounding it; but it was impossible to determine whether the muscular fibre had undergone any fatty degeneration or not.

At first sight the changes which were presented by the trunk and the head and neck appeared very complex indeed.

If one were not already very familiar with the extensive and remarkable changes in form which bones will undergo when they are subjected habitually for a long period of time to the influence of a tendency to produce certain changes in form, one would have felt inclined to relegate some of the conditions which this spinal column presented to that ill-defined class comprised under the terms *congenital abnormality* or *deformity*. I refer to such changes as the prolongation upwards of the transverse process of the atlas and its articulation with the jugular process of the occipital bone. I have seen the beginning of this condition on two previous occasions. However, with the exercise of a little perseverance in the study of the changes of a transitory nature which this portion of the body undergoes in different attitudes, the causation of these phenomena, which were at first very obscure, became clear and well defined. The reader will best see the manner in which the fixed and exaggerated conditions presented by this body were produced by assuming the sedentary posture of the shoemaker while engaged at his work. Let him then fix firmly a last between the chest and the upper aspect of the right thigh, and while he retains the article in this position let him think out carefully what position the several portions of his column, the head, thorax, and pelvis, are occupying. He will then be able to ascertain that the anatomy of this shoemaker represents simply the fixation and subsequent exaggeration of the position and tendencies to change which were present in his body when he assumed the position for a short period of time.

He will find that, in order to exert a suitable and sufficient pressure upon the last and boot, he will rotate his thorax around a vertical axis, as well as around an antero-posterior one. He will throw the left chest forwards, at the same time depressing it, and the right chest backwards, raising it a little also. He will feel that the lower true costal cartilages on the left side transmit a larger proportion of the pressure than those on the right.

In consequence of this position assumed by the chest, the dorsal spine forms a curve with its convexity to the right, while its normal curvature in an antero-posterior plane is slightly increased. This portion of the column is fixed, since the pressure exerted by the last upon the sternum and costal cartilages, and the muscular action brought to bear upon the thorax, in order that it may support this pressure, practically renders it so.

In order that the thorax may be brought into such a vertical level as regards the right thigh, that it may be able to fix the last upon it, it becomes apparent that the fixed dorsal spine is rotated upon the pelvis and lumbar spine by means of a vertical rotation of the last dorsal vertebra upon the first lumbar, of the first lumbar upon the second, and probably in a diminishing degree to the fourth and fifth, since the fifth lumbar does not rotate upon the sacrum around a vertical axis; also, that the normal anterior convexity of the lumbar curve is diminished, the anterior portions of the lower, and especially the lowest, fibro-cartilage being compressed, and a tendency to the forward and downward displacement of the lumbo-sacral articulation being present. Since the sacro-iliac synchondrosis is flexed, there exists a tendency to the induration or the partial or complete removal of the fibro-cartilage where it is compressed between the opposing surfaces of bone drawn violently together by the tightly drawn fibres of the posterior sacro-iliac ligaments, and by the ligaments and fibro-cartilage of the pubic symphysis. The lumbar region must also present a lateral curve, whose convexity is to the left, and the upper extremity of this convexity, since it prolongs the concavity of the dorsal region, must lie to the right of the middle line of the body, as represented by that of the sacrum and pelvis.

The concavity of the lumbar curve is directed to the right. Now, as far as the transmission of pressure is considered, the concavity of the lumbar curve cannot be regarded as being limited to that region, since the right thigh is fixed by the tonic contraction of powerful muscles to the right innominate bone, and the innominate is drawn vigorously to the lumbar spine and right chest; therefore, we must consider the concavity of this arch as being formed by the lower half of the convexity of the dorsal spine, the concavity of the lumbar spine, the upper portion of the body of the sacrum and its lateral mass on the right side, and the innominate bone. Practically, the symphysis pubis may be fairly regarded as forming a portion of the concavity of this arch.

The fibro-cartilages, which enter into the formation of this concavity, must be compressed by the considerable amount of pressure transmitted along it, so that there exists a tendency to their destruction, and to the lipping and subsequent ankylosis of the margins of the adjoining bones.

It is obvious that, as a considerable amount of movement around a vertical axis takes place between the comparatively fixed dorsal spine and the upper lumbar vertebræ, ankylosis will not take place in this region, but that the fibro-cartilages connecting the bodies, and the form and extent of the articular surfaces covering the articular processes of these vertebræ, will be altered in order to allow of free rotation. There will, however, exist a tendency to the increase of the opposing areas of the bodies of the vertebræ, especially in the direction in which rotation takes place by means of the marginal deposit of bone.

In the case of the lowest lumbar and lumbo-sacral articulations, the tendency to the destruction of the fibro-cartilages in the concavity of the curve is still greater; and again in the lower dorsal articulations and in the right sacro-iliac synchondrosis, owing to the comparative fixity of these structures, the tendency to fusion is very much stronger.

It is apparent that both in the movement of flexion of the sacro-iliac joint, and in that attitude which may be regarded as one of abduction of the ilium upon the sacrum, there must exist a strong tendency to the separation of the two pubic bones, both in a horizontal and in a vertical plane. This tendency, if habitually exerted, would lead to an increase in the strength of those ligaments which oppose it.

In sewing the boot the head is held well forwards, directly above the work, on the right thigh. On this account the anterior convexity of the cervical spine is diminished by the compression of the front portions of the fibro-cartilages. The occiput is also flexed upon the atlas, and the transverse ligament and check ligaments sustain much strain. There is also developed a well-marked lateral curve, whose convexity is directed to the left. This curve occupies the upper dorsal and nearly the whole of the cervical region, and the amount of compression sustained by the fibro-cartilages, where they form a part of the right antero-lateral aspect of this portion of the column, is greater than it is in the antero-lateral surface, which corresponds to the convexity of the curve.

Since the head is retained vertically, or nearly vertically, as the base of the skull looks downwards and slightly to the right, the occipital bone and the upper three or four cervical vertebræ form another lateral curve, whose convexity is directed to the right. There must exist, then, a considerable compression of the left antero-lateral portion of the fibro-cartilage, which connects the axis and third cervical vertebra, and to a less degree of that connecting the bodies of the third and fourth.

Owing to the oblique position which the head assumes by performing a movement of rotation around an antero-posterior axis, as already described, and also to a varying and slighter degree around a vertical axis, there must exist a tendency to produce changes in the form of the condyles of the occipital bone and in the superior articular surfaces of the atlas; and these changes would work chiefly in the direction of increasing the areas of the articulating surfaces, and particularly of those on the left side.

I think that it is perfectly fair to assume that during the performance of this work there must also exist a tendency to the development of some formation upon or from the upper surface of the left portion of the lateral mass of the atlas, in order to support the superjacent portion of the base of the skull, and so to counteract a tendency which is present to the excessive rotation of the head upon the atlas around an antero-posterior axis, by means of which very much strain is thrown upon the condylar joints, and the medulla placed in considerable danger.

There cannot, I believe, be any doubt that this is the explanation of the development of the new joint which was present between the strong process of bone, which projected upwards from the left portion of the atlas, and the under surface of the jugular process of the occipital bone.

This growth of bone developed in consequence of the existence of a tendency to its formation, or in other words, as the result of the existence of a demand or necessity for its presence in the same manner and for the same reasons that a similar bone formation extended outwards from the body of the first dorsal vertebra above the head of the first rib. As the occipital bone is habitually flexed upon the atlas, there also exists a tendency to the formation of a joint between the upper margin of the anterior arch of the atlas and the bone forming the anterior boundary of the foramen magnum.

As the shoemaker draws the threads, the head is, on account of its connection with the trunk by means of the cervical spine, thrown somewhat violently and suddenly forwards and downwards. The changes which develop in the neck during this movement may be regarded as constituting a distinct sequence. It is obvious that the first thing to take place is a violent impaction of the odontoid process in a forward and upward direction against the anterior arch of the atlas, which, with the head, is not always retained in really the same angle of rotation around a vertical axis. In consequence of the habitual performance of this movement, there must exist the following progressive tendencies, namely, to the destruction of the articular cartilage, which covers the opposing surfaces of the odontoid process and arch of the atlas; to the eburnation of the exposed bone; to the excavation and increase in area of the facet on the atlas, both laterally and vertically, the tendency to the increase of the vertical diameter being upwards beyond the normal upper limit of the anterior arch; and to the corresponding and commensurate increase in the height of the odontoid process by the deposit of bone along its upper limit. The sudden increase of the flexion of the cervical and upper dorsal spine, and especially of the adjacent portions of these two sections of the column, produced by the abrupt forward and downward movement of the skull, develops a very strong tendency to the formation of an excessive amount of marginal bossing and anchylosis of the margins of the bodies of the vertebræ, since the conditions are quite distinct from those in which pressure, however considerable, is transmitted steadily through bones and fibro-cartilages. They correspond rather to those which are present in the case of such fractures as are mended by that form of callus which is technically described as *provisional.*

A great amount of dense bone, which was present in the anterior surface of the cervico-dorsal region of the column of the shoemaker, was obviously dependent for its causation upon these mechanical conditions.

The joints in the centre of the cervical region escaped any considerable lateral destruction, for the reason that the bodies of these vertebræ did not form a very prominent portion of the lateral curve, and because the abrupt primary movement of the column and the equally sudden movement of the skull in an antero-posterior place necessitated a certain freedom of movement in this region around a transverse axis.

I will not weary the reader by describing all of the very numerous changes which the spinal column and pelvis of this workman had undergone in consequence of the existence of the tendencies I have related. It is sufficient to state that they were such as one would expect to find in *a priori* ground. I must, however, describe briefly the conditions presented by the upper portion of the cervical column and by the occipital bone, since they were unusual in character.

The left half of the body of the axis, as is shown in Pl. XIX. fig. 3, was in great part united by bone to the corresponding portion of the body of the third cervical vertebra. The articular processes, laminæ, and spinous processes of these vertebræ were on the left side connected by bone. This fusion of the laminæ had obviously not resulted from the forcible opposition of these portions of the vertebræ, but represented apparently an ossification of the ligaments connecting them. There was some similar growth on the right side, but it was much less abundant than on the left. The position of the original joint between the articular processes of these vertebræ was indicated by the presence of a prominent oblique elevation. There was some bossing of the margins of the articular processes of the vertebræ immediately below on the same side, namely the third and fourth.

The odontoid process was peculiarly modified in form. Its height was increased by the projection upwards from the anterior portion of its upper extremity of a thin curved plate of dense bone. Both this additional process of bone and the adjacent portion of the odontoid process presented upon their anterior surface a continuous densely eburnated polished facet, which was convex from side to side. It was subdivided into two portions which occupied different vertical places, that on the normal odontoid process lying in front of the one above it.

There was a large vertically oval facet on the back of the odontoid process. This was covered by articular cartilage, and articulated with an abnormally well-developed transverse ligament. Its surface was convex from side to side, and encroached slightly upon the lateral aspects of the process.

The remainder of the bone was rough for the attachment of check ligaments, which were also very well developed.

An accessory transverse ligament, which was attached to tubercles immediately internal to the anterior portions of the condyles of the occipital bone, lay in front of the check ligament and behind the upward prolongation of the odontoid process. It was apparent that it performed a function similar and accessory to that of the normal transverse ligament. This structure I have indicated in fig. 2. The atlas presented three distinct variations, one of which at least was very remarkable. The condylar facets on its upper surface were unequal in extent, the left being longer from before backwards; a prominent little knob of bone projected upwards, backwards, and outwards from the posterior limit of this facet.

The anterior arch was deeply excavated posteriorly. Its depth was nearly doubled by the deposit of bone upon its upper and lower margins, the amount of new growth above being very abundant, while that below was scanty. The large cup-shaped facet occupied the whole increased depth of the arch. Its surface was highly polished and densely eburnated. It was subdivided into two parts by a slight ridge which ran transversely across its surface. On articulating this bone with the axis, the facet described on the anterior surface of the odontoid process, and upon its upward prolongation articulated with the two parts of the atloid facet. Its upper margin was very irregular, and overhung the floor of the cavity. On articulating the atlas with the occipital bone, the irregular upper margin of the atloid facet fitted into and occupied an irregular narrow groove with prominent edges upon the under surface of the anterior margin of the foramen magnum. This I have tried to illustrate in fig. 2. From the upper surface of the transverse process of the atlas immediately outside and behind the vertical foramen, there projected vertically upwards a strong process of bone which was flattened from side to side. Its extremity was broad, and presented a quadrilateral rough facet upon its upper surface. This articulated with a corresponding depression on the under surface of the jugular process of the occipital bone immediately internal to the groove which attaches the posterior belly of the digastric muscle. A small synovial cavity surrounded this acquired articulation, but there was no appearance of a capsular ligament. This process of bone and the increased depth of the anterior arch are shown pretty clearly in fig. 1.

As the head is thrown forwards with considerable violence, and especially at the termination of this forward movement, the odontoid process exerts a very great strain upon the transverse and check ligaments. The presence of this strain tends to produce the better development of these structures which oppose the backward displacement of the process of the axis.

We find here in this shoemaker, whose anatomy I have described, another remarkable instance of the manner in which the organism will provide, almost as if by instinct, if I might so use the term, a structure which is definite in its form and in its capacity for performing a certain function in response to a tendency or a necessity for its existence. I refer more particularly here to the additional transverse ligament which lay behind the upward prolongation of the odontoid process, and was attached on either side to the margin of the foramen magnum, and which opposed its backward displacement. It is quite obvious that this transverse ligament could not have existed before the odontoid process was prolonged to its level, and that it appeared and performed its function only when the necessity for its existence arose. Its development is but one instance of a law which is abundantly illustrated by the anatomy of this subject. It is difficult to understand the exact manner, and from what such a definite structure is developed. The higher mammals are unable to reproduce portions of their body which are destroyed or injured. *They possess, however, a much more remarkable power, which, I think, is the most important factor in evolution.*

It is that they are able to produce, in response to a tendency to its development, which tendency has arisen in consequence of the individual being subjected to the influence of mechanical forces other than those that determined his evolution, a more or less complete change in the character of the anatomy and physiology of a part or of the whole of their bodies.

If it is impossible for this tendency to result in its actuality *during the lifetime of that individual, it is able to transmit that tendency to change to its offspring, in which it may produce the actuality.*[1]

I recently applied this law to explain the changes which the skeleton undergoes in abnormal conditions, as mollities ossium, rickets, osteitis deformans, and congenital syphilis; and I was able to satisfy myself completely on its applicability to this subject.[2]

While sewing, the thighs are flexed upon the trunk and are retained firmly in this position, in order to retain the boot and last in position, by the exercise of a considerable amount of muscular energy. By this means the upper surface of the head of the femur is retained in firm contact with the back part of the acetabulum, so that there exists a certain tendency to the displacement of the head directly backwards. In response to this tendency there is developed on the posterior margin of the acetabulum a sharp prominent ridge of bone, and the cotyloid ligament is prolonged outwards over this.

I had never before seen such a growth of bone and fibro-cartilage upon this portion of the acetabular margin, though it is readily developed, and is frequently present in response to a similar tendency upon the upper or upper and posterior portions of the margin of the cavity in many occupations, and in morbid conditions in which the trunk is retained in a position of flexion upon the thigh.

Owing to the habitual and considerable flexion of the hip-joint, and the consequent apposition of the articular surface of the acetabulum with the non-articular portion of the neck of the femur, the articular surface of the head had been prolonged downwards and outwards over the neck by the direct conversion of the synovial membrane into articular cartilage and bone. The appearance presented by these extensions of articular cartilage upon the neck of the femur vary considerably and definitely with the cause which determines their production, and one might write a great deal about them. As in most sedentary occupations, bursal cavities of considerable size had developed in consequence of the habitual pressure sustained by the tuberosities of the ischium.

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[1] "Can a Tendency which produces no Change in the Parent result in the actuality of the Change in the Offspring," *Journ. of Anat. and Phys.*, 1887.

[2] "The Factors which determine the Hypertrophy of the Skull in Mollities Ossium, Rickets, Congenital Syphilis, and Osteitis Deformans," *Proc. Roy. Med. Chir. Soc.*, 1887, and *Lancet*, May 1888.

The changes which the shoulder girdles undergo in this occupation are very definite and characteristic.

After the hole has been made in the leather by means of the awl, the waxed threads are passed through it. Their ends are then grasped firmly in the hands, one being usually twisted round the awl held in the right hand, while the other is made to encircle the palm, which is guarded from injury by a suitable leathern shield.

By means of a sudden and violent jerk the shoemaker pulls the threads through the hole, and by abducting and extending his shoulder-joints he continues to separate his hands till he has pulled through the whole of the slack. He then gives the threads an additional jerk, expending, as in the first movement, a great deal of muscular energy.

It would be impossible to pull the threads through the hole made by the awl without applying to them the sudden initial strain. It is therefore apparent that the greatest amount of energy is expended upon the commencement of the movement, though throughout it all much force is exerted.

Since the right upper extremity is used in performing some movements in addition to those performed by the left, we would expect to find in the right shoulder-joint less exactly defined indications of a single succession of movements than on the left side. I refer to such movements as hammering, polishing, &c. It is apparent, from a little consideration, that these movements can tend to produce but very slight modifications in the characters of the bones and joints, as compared to those which must result from the habitual performance of the sewing movement for a long period of years. If we analyse the mode and direction by which force is transmitted from the upper extremity to the sternum and first costal arch in this movement in order to determine the tendencies to change which are developed during its performance, we see that at its commencement the clavicle occupies a position of slight flexion and adduction upon the manubrium and first costal arch, and that at its termination it is in a position of extreme extension and abduction. The outer extremity of the clavicle has passed in a straight line, running from below, upwards and backwards, its inner extremity moving upon the sternum around an axis, whose direction is from above, downwards and backwards. Since this is the only movement which takes place habitually in the sterno-clavicular articulation, it becomes for all practical purposes a hinge-joint, and the opposing surfaces of bone tend to assume the form most useful for the performance of such movements, a tendency existing to the increase of the size of the inner extremity of the clavicle and of the area of the articular cavity formed by the manubrium and first costal cartilage; to the excessive elongation of the inner extremity of the clavicle in the direction of the axis of rotation; to rendering the inner surface of the clavicle convex in a direction which crosses the axis of rotation at right angles, namely, from above, downwards and forwards, and to changing the form of the costo-sternal facet, that it shall accommodate the inner extremity of the clavicle in its altered form.

In drawing the threads the clavicle forms the resultant of a parallelogram of forces, one acting in a direction from without, downwards, forwards, and inwards, and corresponding to the resistance which the leather offers to the passage of the waxed threads, and the other in a direction from without, upwards, backwards, and inwards, and corresponding to the strain exerted by the trapezius, levator anguli scapulæ and rhomboid muscles, as they draw the scapula and the outer end of the clavicle upwards, backwards, and inwards.

Though the general direction of the force which is transmitted along the clavicle during the whole of the movements is inwards, yet the exact direction varies considerably at different periods of the movement.

For instance, at the commencement of the movement, when the clavicle is transmitting the greatest amount of pressure, the direction which it takes is upwards, inwards, and backwards, so that there exists a tendency to the displacement of the inner end of the clavicle upwards and backwards; to the destruction of the fibro-cartilage where it intervenes between the anterior portion of the inner end of the clavicle and the sternum, and of the articular cartilage covering the thin opposed surfaces of clavicle and sternum; and to the hypertrophy of the ligaments, which oppose such a tendency to displacement of the sternal end of the clavicle. These ligaments are the posterior and upper portions of the capsular ligament and the interclavicular.

At the end of the movement the clavicle is transmitting pressure to the sternum in a direction from without, inwards, forwards, and downwards, so that there exists at this period a tendency to the destruction of the posterior and upper portion of the interarticular fibro-cartilage where it intervenes between the posterior and upper part of the facet on the clavicle and the sternum; to the removal of the articular cartilage covering the articular surfaces of the clavicle and sternum, which come into immediate apposition after the destruction of the intervening fibro-cartilage; also to the eburnation of the exposed bone; to the hypertrophy of the ligaments opposing the movement, and possibly to their elongation, if the movement performed be extreme, as it is in this case, and the ligaments showing this change are the anterior sterno-clavicular and rhomboid ligaments, the costo-coracoid membrane, and the subclavius, much of the substance of which tends to retrocede under the influence of the strain it experiences; to the displacement of the inner end of the clavicle forwards and downwards, and to the elevation of the anterior margin of the chondro-sternal facet, in order to oppose this displacement.

In an intermediate position of the movement between these two extremes the pressure is transmitted almost directly inwards along the clavicle, and the tendency to produce definite and similar changes is quite obvious.

The influence of the very considerable amount of force which is exerted inwards along the direction of and by means of the clavicle, added to the movement of the outer extremity of the clavicle in an oblique plane around an axis which passes at right angles to that plane through the sterno-clavicular articulation, tends to exert a very powerful influence, and finally results in the conversion of the very complex arthrodial sterno-clavicular joint into the joint of the aged shoemaker, which may be regarded as almost a perfectly ginglymoid articulation. The inner extremity of the clavicle had completely lost its normal form. It was enormously increased in size, and formed an oval extremity whose long axis ran from above downwards and slightly backwards. This diameter of the inner end of the clavicle measured 1¾ inches, while its breadth was under an inch.

The structure of the sterno-clavicular articulation as a normal and permanent mechanism is remarkably ill adapted to the performance of heavy muscular labour. When it is subjected habitually to any great strain for a long period of time, it undergoes very extensive changes at a comparatively rapid rate, and the variations which are developed vary within wide limits with the form of the occupation, and therefore with the character of the laborious movements which this joint is called upon to perform habitually.

We will take, for instance, that portion of the joint which, from its definite form, structure, and attachments, shows most distinctly any alteration. I have examined a great many sterno-clavicular joints in labourers, but have never seen one in which the fibro-cartilage had been so completely removed as it had been in this shoemaker, nor in which the inner end of the clavicle and the chondro-sternal facet had undergone such extreme and remarkable changes in form and character; there is, however, not the slightest difficulty in understanding the manner in which this complete change was brought about by the habitual movements of this workman.

The nearest approach to it which I have observed was in the body of a powerfully-built sailor. In that case the fibro-cartilage had lost its attachment to the clavicle as well as to the sternal portion of the joint. The only relic of the original structure was a densely-fibrous wedge, containing minute particles of bone scattered through its substance. This was attached to the upper portion of the capsule of the joint by its base, and, projecting downwards, occupied the angular interval which existed between the two bones above. I have indicated this in fig. 6. We are aware that the sailor performs a great many movements of different kinds with his arms, in which he exerts a considerable amount of muscular energy. Yet, though they would seem to form a very complex group, I think we can at once separate from them all those in which an immense amount of strain is thrown upon the sterno-clavicular articulation. The other movements, as climbing, &c., may demand the expenditure of much muscular exertion, but in them the sterno-clavicular articulations do not transmit the same amount of pressure. I refer particularly to two movements, one in which an immense pressure is exerted in a forward and downward direction upon the outer end of the clavicle, which occupies a position of flexion and adduction at its sternal articulation, and resting upon the first cartilage, as in pulling upon a rope which passes through a pulley on a level with the deck. In the other movement a corresponding amount of pressure is exerted upon the outer part of the clavicle in a backward and downward direction, that bone being extended completely upon the sternum, and resting upon the first rib. This takes place when the man hauls in a rope which passes from behind over his shoulder. There are many other similar movements in which force is exerted upon the clavicle, either in these directions and positions, or in intermediate ones, but the two extremes which I have given serve to illustrate my point. In the first the anterior portion of the lower half of the fibro-cartilage intervenes between the surfaces of clavicle and sternum through which the force is transmitted, and it is rapidly destroyed; while in the second movement the posterior half of the lower section of the fibro-cartilage is compressed and finally obliterated. The dense wedge of partly ossified fibro-cartilage which remains serves a certain, obvious, definite, and useful purpose. I might describe the varied conditions of this joint which are present in very many forms of labour, since in every one who has performed habitually any kind of heavy manual exercise some change is always present. I think, however, that the examples of the shoemaker and sailor serve to illustrate sufficiently fully and clearly for the limits of this paper the truth of my statement.

Owing to the exact similarity of the movements of the two arms in sewing, each clavicle must impinge upon the same spot upon the costal arch. In consequence of this, one would expect to find but a very small chondro or costo-clavicular articulation present in the substance of the rhomboid ligament, and the opposing articulating surfaces very small and well-defined. The large amount of pressure which the clavicles exert upon the first costal arch, together with the necessity of the fixation of the arch as regards any rotation of it or of the manubrium around an antero-posterior axis, would assist materially in producing an early ossification of the first costal cartilages, in the development of strong amphiarthrodial joints in their substance, and in rendering the manubrio-gladiolar articulation rigid as regards movement of the manubrium upon the gladiolus around any but a transverse axis.

Nearly the whole of the force which is transmitted in an inward direction by the clavicle to the costo-sternal articulation must be applied to the outer end of the clavicle by the acromion process of the scapula.

Therefore, it is quite obvious that there must exist two tendencies to produce change in the form of this bone, which normally presents two curves in the same plane. One tendency is to produce a local change. By that I mean an alteration in the direction, form, and character of the acromial facet, and in the shape of the bone immediately adjacent to it. The second tendency is to increase the curvatures of the clavicle, and so render it shorter.

Many points of extreme interest and importance arise in connection with the discussion of the results produced by these tendencies.

In the normal acromio-clavicular articulation, as it exists in the young subject, the plane of the opposing surfaces forms nearly an equal angle with the vertical and the horizontal planes; in most cases the former is a little the smaller. In many of the quadrumana which I have dissected, I have found that the plane of the opposing facets formed with the horizontal plane a similar angle.

The great advantage of such a joint in this situation is particularly obvious in these animals, since they are so habitually engaged in supporting themselves by their upper extremities. While in this attitude there exists a tendency to the separation of the opposing articular surfaces, so that if they were vertical and were separated in consequence of the strain exerted upon the joint, a vacuum must be formed between the bones. By means, however, of the obliquity of the plane of the facets, the joint can be extended very considerably without the formation of any vacuum between the bones, or in any way limiting the freedom of movement or diminishing the security of the forcibly extended joint. The same mechanism is again made use of in the sterno-clavicular articulation in many of these small quadrumana, where it serves the same useful purpose, giving remarkable freedom of movement and strength and security to the joint. The anatomy of these joints in man and in quadrumana will, I hope, form the subject of a future communication, in which I hope to discuss very fully the factors which determine the several variations they present.

I will at present restrict myself to saying that the normal condition of the acromio-clavicular articulation is extremely ill-adapted to the performance of any laborious occupation, so that it at once undergoes a complete change when such work is engaged in.

In the normal joint I have been unable to find any fibro-cartilage present. Its development I will show to be what I might term a " suction change," due to factors other than those which determined the form of the so-called normal condition.

In association with the movement of abduction and extension of the shoulder-joint, the scapula undergoes a movement upwards, inwards, and slightly backwards, but it also apparently rotates slightly upon an antero-posterior axis. The outer end of the clavicle follows the acromion in its movement, chiefly on account of its connection to it by ligaments, the trapezius also influencing it considerably in doing so. The normal obliquity of the opposing facets must therefore be replaced at an early period of the individual's labour history by articular surfaces lying in a vertical plane. Since the acromial facet moves from before backwards upon the clavicle in the form of an arc of a circle, and since the pressure sustained by the opposing surfaces of clavicle and acromion is greatest at the commencement of the movement, the facet on the clavicle is larger and deeper than that upon the acromion, it is slightly convex from before backwards, its anterior portion is much more polished and eburnated than its posterior part, and the deposit of bone upon its upper margin and upon the adjacent surfaces of the clavicle is much more abundant than upon its lower. The facet on the acromion is smaller, and is slightly concave from before backwards. These local changes in the outer extremity of the clavicle are illustrated remarkably well by the anatomy of the shoemaker.

In the normal acromio-clavicular joint there is a very strong superior ligament, which is attached to the upper surface of the posterior margin of the outer extremity of the clavicle. The fibres forming this ligament run forwards and outwards to the upper surface of the acromion process. The structure of the remainder of the so-called capsule of this joint is very thin. In this case there did not exist a tendency to the displacement of the acromion in a forward and downward direction, as in the normal subject when the arm is hanging by the side, but there was developed a tendency to its displacement upwards and backwards. In consequence of the presence of this tendency, the character of the ligaments of this joint changes, and the direction of the fibres of the superior ligament was altered, and a thickening was formed in the lower portion of the capsule in what may be regarded as a well-developed specimen of the genus shoemaker.

At the end of the movement of abduction and extension of the humerus at the shoulder-joint, and to a less extent throughout the whole of it, the scapula bears to the clavicle, in its articulation with it, a position the reverse of that which it occupies in extreme flexion of the shoulder-joint. I have described the latter relationship in a paper[1] which I read recently before the Royal Medical Chirurgical Society, in which I showed its importance from a surgical aspect. The former relationship we may fairly describe as one of extension. In this position the upper portion of the root of the coracoid process, namely, the surface immediately in front of the conoid tubercle, comes continually into contact with the under surface of the clavicle, the conoid ligament is retained in a condition of relaxation, and the trapezoid ligament in a state of habitual compression. In consequence of this, the conoid ligament becomes short, and forms part of the capsule of a coraco-clavicular articulation which is developed in this situation, while the atrophied trapezoid ligament remains in the cavity of this joint.

I have never, except in the case of the shoemaker, seen a coraco-clavicular articulation developed on this portion of the coracoid process. The explanation is, that in no other occupation which I have had an opportunity of examining has the scapula been retained habitually in such a position of extension upon the clavicle. In a large number of labours, however, the scapula is retained in a position of forcible and extreme flexion upon the clavicle, and this accounts for the frequent presence of a joint in relation with the anterior portion of the upper surface of the coracoid process.

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[1] "A Mode of Fixation of the Scapula, and its bearing upon the Mechanism of Fracture of the Coracoid Process," *Proc. Roy. Med. Chir. Soc.*, 1887, and *British Medical Journal*, May 19, 1888.

As regards the result of the second of the two tendencies which exist, namely, to produce a shortening and increased curvation of the clavicle, I have but little doubt that the habitual exercise of a considerable force, such as that present in the shoemaker, is sufficient to produce, at least during young and early adult life, some such considerable change in the general form of the bone as was present in this subject.

We see a similar change in the form of the long bones of the lower extremity under the influence of habitual pressure in the case of children who ride constantly bare-back; or in the flat bones, as in the shoemaker's sternum. At the same time, I think we must allow that the extent of the change in form bears direct proportion to the loss of tone and vigour by the individual.

In the case of the shoemaker it is particularly difficult to measure the exact amount of increased curvature which is due to the exercise of this pressure, for another factor is present which complicates the problem very considerably. This is, perhaps, not quite so apparent and distinct in the case of the clavicle as I think I can make it in that of the scapula. It is an instance of what should be a well-known law, but one which does not receive the attention it deserves, nor is it applied as frequently or as generally as it ought to be. *It is that, in proportion as a muscle is exposed habitually to constant and considerable strain, in the same proportion do its muscular fibres tend to retrocede to tendon, and the bony surfaces into which it is inserted tend to grow in the direction of the traction which the muscle exerts upon them.* In the case of the clavicle, I refer particularly to the whole of the insertion of the trapezius into it, and to a portion, namely, the outer, of the clavicular attachment of the deltoid.

The same principle is illustrated in this subject by the subclavius muscles, which were so habitually exposed to considerable and sudden strain. Much of the muscular fibre of these muscles had retroceded, if one might so apply this term, to tendon, ligament, and fascia. Since, in the movement of sewing, the extremity of the coracoid process is not separated more than normally from its costal attachment, but is, on the contrary, approximated to it, the thickening which is frequently present in the costo-coracoid membrane was not obvious in this subject, for the reason that there existed no necessity for its existence or tendency to its development.

Now, let us attempt to apply the law which I have just formulated to the case of the scapula of the shoemaker. In the movement of the arms in sewing the boot, the scapula is drawn upwards, inwards, and backwards in an oblique plane, the bone undergoing but a slight degree of rotation around an oblique antero-posterior axis.

Since this movement of the scapula is opposed by the very considerable resistance which the leather affords to the passage of the waxed threads through it, the amount of force exerted by the muscles which produce this movement of the bone must be very great. The muscles are the trapezius and rhomboids, and to a very slight degree the levator anguli scapulæ. We would therefore expect to find, in one who habitually performed this labour, that the surfaces into which the trapezius and rhomboid muscles were inserted were very thick and prominent, and in the case of their being marginal, that they were prolonged in the direction in which traction was exerted upon them. This was very marked in this subject. I have indicated in outline, in figs. 7 and 8, many of the most conspicuous characters of the right scapula.

The insertion of the trapezius was very broad and conspicuous, and its large area served to assist in producing abnormally great breadth of the posterior free margin of the spinous process. The inner margin of the scapula formed two prominent convexities, which were developed in the direction of the traction exerted upon that border by the rhomboid muscles.

The humerus is moved upon the scapula from a position of adduction and partial flexion to one of extreme abduction and of considerable extension. As this movement is violently opposed, a great amount of force must be exerted by the muscles which produce it, and a corresponding amount of strain must be experienced by the portions of the bones into which these muscles are inserted.

The muscles which are chiefly engaged in performing the movement are the supraspinatus and the central and posterior portions of the deltoid. The anterior portion of the latter muscle takes a minor share in the production of the movement. The influence of the traction exerted by the supraspinatus upon the scapula is indicated by the very considerable eversion of those margins of the scapula into which its muscle and aponeurosis are inserted, namely the whole of the upper and that portion of the inner which is above the level of the spinous process. I have endeavoured to represent in fig. 8 a view of the vertebral margin of the scapula as seen from the middle line of the body, and by means of the dotted line I have indicated the outline of the venter of the scapula, corresponding to the floor of the supraspinous fossa. Besides showing the great depth and extent of this fossa, it also gives some idea of the amount of eversion of its vertebral margin. In the same manner the traction exerted by the supraspinatus upon this margin had so influenced the position of the upper angle of the scapula, that the angle which is enclosed between a line joining the upper angle and the inner limit of the spinous process, and one joining the latter point and the lower angle of the scapula, is abnormally small.

The strain exerted by the deltoid upon its scapular attachment has resulted in the enormous increase in the antero-posterior measurement of the free outer margin of the acromion, which has developed in an outward and backward direction, and it has assisted in the production of the great breadth of the posterior free margin of the spinous process.

The spinous process and acromion showed a greater increase in size than any other portion of the scapula. The breadth of the posterior margin of the spinous process measured at two points $\frac{5}{8}$ and $1\frac{1}{4}$ inches respectively, the measurements of the corresponding points in an average scapula being $\frac{1}{2}$ and $\frac{15}{16}$ inch. The outer margin of the acromion measured $3\frac{1}{8}$ inches as compared to an average measurement of $1\frac{3}{4}$ inches. The plane of the clavicular facet was vertical, its area was enormously increased, and its surface was densely eburnated. The insertion of the deltoid into the humerus was indicated by the presence of a mound of rough bone which was very much larger than anything I had ever seen in this position.

A consideration of the direction in which force is exerted by that portion of the deltoid which is chiefly engaged in the performance of the movement of abduction and extension of the humerus, and the mechanical advantages which such a prolongation of the acromion affords, renders obvious the manner in which the acromion has altered its form in response to the tendency to such a change which is habitually present.

Perhaps I can best illustrate some of the changes in form which the scapula undergoes by describing very briefly the chief characters which it presents in another form of labour, in the performance of which a different set of movements are carried out and force is exerted along somewhat different directions.

Fig. 9 represent the posterior surface, and fig. 10 the vertebral margin of the scapula of a labourer, who had apparently been engaged habitually in carrying loads of considerable weight upon his right shoulder. In order to render the comparison as complete as possible, I have chosen a subject of about the same age as the shoemaker. This has, however, the disadvantage of introducing two complications, since the labourer had not performed any very laborious work for some years before his death, and his skeleton presented senile changes which were absent in the shoemaker.

These circumstances will not interfere materially with the points to which I wish to call attention. In supporting a heavy and moderately bulky load, such as this man was in the habit of carrying upon the shoulder and upper portion of the back of the thorax, the muscles which oppose the greatest resistance to the displacement of the scapula are the trapezius and the levator anguli scapulæ, the rhomboids performing a smaller share of the work. The strain thrown upon the deltoid, the lower portion of the subscapularis and teres major muscles is considerable; while that sustained by the supraspinatus is comparatively trivial. Consequently, we find in this scapula that the supraspinous fossa is shallow, that there is not the slightest eversion of its upper or inner margins, that the vertebral margin, when regarded from the middle line of the body, presents a very perfect arc of a circle, beyond whose concavity the venter of the scapula is not seen to project; that the attachments of the deltoid and trapezius are well marked and extensive, rendering the posterior free margin of the spinous process very thick, and the outer border of the acromion longer than usual. The prolongation of the upper angle of the scapula in the direction of the traction exerted by the levator anguli scapulæ is very obvious, and the convexity of the vertebral margin in the situation of the insertion of the rhomboideus major, and the extensive surface of origin of the teres major and of the lowest intramuscular tendon of origin of the subscapularis are very well defined. To discuss this scapula more fully we ought to consider the many interesting characters which were presented by the upper extremity of the humerus and by the clavicle, but these I will leave for the present, as they would occupy too much space.

A consideration of these and other changes will show how useless it is to attempt to draw any definite conclusion from the formation of an average form of scapula or other bone from a number of such bones, collected together quite irrespective of the occupations or habits of the individuals from whom they were obtained. In such a study we cannot be too careful of the most minute detail, and the variations cannot be grouped under any single so-called index.

Other results of the same habitual strain exerted by those two muscles in the shoemaker are the extensive prominence of the insertion of the deltoid and the formation of a dense plate of fibro-cartilage in the tendon of the supraspinatus.

The infraspinatus and the two teres muscles exert a considerable amount of force in the production of the movement, though it is very much less than that exerted by the deltoid and supraspinatus. Therefore, we see that the markings on the scapula indicating the origins of the former muscles are proportionately less well marked than are those of the latter.

In the movement of the humerus upon the scapula the head of the former must articulate with an oblique oval area of the glenoid cavity, whose direction runs from above downwards and forwards. There must, in consequence, exist a tendency for the shape of this cavity to change and to form an oval articular facet, its long axis having the direction I have indicated; also for the unused portion of the original articular surface to undergo changes consequent upon the absence of those movements, upon the presence of which it is dependent for the perpetuation of its normal form in the same manner that its original form was evolved by their acquisition. Also since the force exerted by the muscles upon the arm in the production of the movement, and the resistance offered to it, are greatest at its commencement, where the lower limit of the articular surface of the head of the humerus is in contact with the anterior and lower portion of the margin of the glenoid cavity, there must exist at that period a great tendency to the displacement of the head of the humerus downwards and forwards from the articular surface of the scapula. The presence of this tendency results in the development of a process of bone from the margin of the cavity, which runs outwards and forwards, and opposes this tendency to displacement. It is covered by articular cartilage. By this means the direction of the surface of this cavity becomes altered. It no longer looks directly outwards and slightly upwards, as in the normal subject or in the quadrumana, forming nearly a right angle with the plane of the body of the scapula, but it looks outwards, backwards, and upwards, as I have indicated in the diagram. I have already shown that, under the influence of strain which is exerted vertically downwards upon the shoulder-girdle by means of the humerus for considerable periods of time, as in carrying heavy loads in the hands, the surface of the glenoid cavity undergoes a change in its normal direction. The shoulder girdle is subjected habitually to such mechanical influences in occupations such as milkmen, a dissected specimen of which I have described in this *Journal*, p. 394, 1886—" Some Variations in the Human Skeleton."

It would therefore appear that a very considerable strain, exerted habitually in a downward direction by the humerus upon the shoulder-girdle for a long period of time, results in a gradual destruction of, or diminution in, the growth of the anterior margin of the glenoid cavity, and possibly an excessive growth of its posterior margin, causing the surface of the glenoid cavity to look outwards and forwards, instead of outwards, as it does in the normal subject; also, that the momentary exercise of a sudden and considerable amount of strain, tending to displace the head of the humerus forwards and inwards from the scapular facet, results in changes in the form of that cavity the reverse of these just described, namely, an overgrowth of the anterior margin, and possibly a decrease in the extent of the growth of the posterior, causing the articular surface to look outwards and backwards. The character of the details of the changes depend largely in either case upon the age of the labourer when he commenced the particular form of occupation. This holds good for all labour and other pressure changes. This subject of the change in direction of the surface of the glenoid cavity in a horizontal plane is complicated by alterations in its direction in a vertical plane, so that in some cases the surface may look outwards, forwards, and upwards, and in others outwards, backwards, and downwards. In other cases there may be different combinations. In almost all the bodies which I have examined throughout, I have found myself able to explain the causation of the variation in the direction of the articular surface on simple mechanical principles, obtained from a study of the details of the particular work performed. I will not proceed further with the consideration of this subject in this paper, but will return to the consideration of the anatomy of the shoemaker.

The habitual performance of the movement determines a very distinct alteration in the shape of the articular surface of the upper extremity of the humerus, as in that of the glenoid cavity. The articular surface of the bone is rendered much more extensive than usual by the prolongation of the original facet in two directions. At the same time two portions of the original head have become functionless, since in the habitual movement they do not come into contact with the articular surface of the glenoid cavity. In consequence of the alteration in their function, the cartilage and subjacent bone undergo a series of changes which I have frequently described and illustrated. The portions of the head which undergo these changes are the anterior and upper portion, and the lower and back part. The resulting articular facet corresponds in form and direction to that presented by the glenoid cavity, its long axis running from above downwards and forwards. The lower portion of the original head has been prolonged downwards and forwards, and ends in an abrupt margin, which corresponds in position and in causation to the growth of bone and cartilage upon the anterior margin of the glenoid cavity. If the humerus and scapula be placed in the position they occupy at the commencement of the movement of drawing the thread, the surface of the scapula is seen to be directly continuous by means of the marginal growth on the scapula and head of the humerus, with the surface of the neck of the humerus forming a complete arch. At the end of the movement it is observed that the upper and back part of the glenoid facet is in contact with the prolongation upwards, backwards, and outwards of the original articular surface of the head of the humerus.

In this shoemaker the long axis of the articular surface of the head of the humerus measured $3\frac{1}{16}$ inches, while its greatest breadth did not exceed $2\frac{2}{16}$ inches. The average diameter of the nearly circular articular surface in the normal vigorous adult measures about $2\frac{3}{4}$ inches.

The causation of the anatomical characters presented by the upper extremity of the shoemaker is very simple and obvious, and its consideration will not delay us long. The work done by the arms is very constant and considerable, and we therefore expect to find the bones larger than usual, the ligaments strong and thick, and the muscles well developed and in good condition.

The reader can readily understand the manner in which the several changes have been produced by assuming the attitude of the shoemaker, and by grasping cords which are connected to a central fixed point in the hand, the cord in the left hand being made to encircle the palm, and that in the right hand being attached to an awl or similar instrument held in it. Let him suddenly exert traction of a violent nature upon the strings in the direction and manner I have already described. He will then be able to determine accurately the tendencies which exist during the performance of the single movement to deviation from the normal typical anatomy, and from a careful consideration of them he can arrive at the resulting changes which must develop in consequence of the very habitual existence of these powerful tendencies.

I will now enumerate the several tendencies to change which exist, and by referring to the anatomy of the shoemaker, the reader will be able to verify the existence of the tendencies by the presence of their actuality in that subject. In consequence of the great strain thrown upon the long tendon of the biceps as it passes over the projecting angle formed by the upper portion of the bicipital groove, a tendency exists to its acquiring an attachment to the floor or margins of that groove and to the dissociation of the portion of the long head which intervenes between that point and the glenoid cavity. The same great strain which is experienced by the tendon of insertion of this muscle while the fore-arm is pronated and flexed upon the humerus tends to produce an increase in the size and prominence of that portion of the tubercle into which the tendon is inserted, and in the area of the bursal cavity and articular surface of the tubercle in front of that insertion.

The same violent traction exerted by the biceps, especially at the commencement of the movement, assisted by that exerted by the supinator longus, tends to displace the head of the radius upwards and backwards from the position it occupies in this act, and to produce a proportionate increase in the thickness of the ligamentous structure which is chiefly engaged in opposing that displacement, namely, the interosseous membrane.

Since the opposing surfaces of radius and ulna are brought into comparatively forcible opposition only when the fore-arm occupies a position of pretty complete pronation, there exists a tendency for the portions of the articular surfaces so engaged to retain their normal articular covering, and to become more or less abruptly defined from the remainder of the articular surfaces, which, owing to their not performing the functions they are present to perform, undergo changes to adapt themselves to their altered circumstances.

The strain exerted upon the radius away from the elbow, and in the direction of the string, by the ligaments of the wrist and by the muscles which are attached to the radius, whether directly, or indirectly by means of the interosseous membrane, tends to produce a displacement of the radius in that direction, a hypertrophy of the oblique radio-ulnar ligament, the external lateral ligament, and the portion of the anterior and posterior ligaments of the elbow-joint which oppose the displacement of the radius, and the development of a vacuum in the elbow-joint.

In consequence of the presence of this last tendency we would expect to find in one who had been engaged in this occupation for many years a nearly complete synovial fringe of a firmness and size proportionate to the duration and severity of the work performed, occupying the slight interval existing between the radial head of the humerus and the head of the radius where these surfaces are separated by the traction exerted upon the latter bone; also a very considerable hypertrophy of the intra-articular processes of synovial membrane, connective tissue and fat, which occupy the lateral notches in the articular surface of the great sigmoid cavity and the coronoid and olecranon depressions.

The habitual retention of the hand in a position of flexion, and of considerable adduction upon the pronated fore-arm, tends to produce an extension of the superior articular surface of the upper row of the carpus downwards upon the anterior surface of the scaphoid, semilunar, and cuneiform bones, and a consequent displacement of the attachment of the anterior radio-carpal ligaments downwards upon it; also a more abrupt definition of the posterior or ligamentous sections of the facets upon the upper surface of the scaphoid and semilunar bones. While the hand is in this position, the anterior surface of the styloid process of the ulna is retained in forcible contact with the inner surface of the cuneiform bone, and there exists in consequence of this a tendency to the formation of facets upon the opposing surfaces of bone and of a surrounding capsule, and so to the evolution of a complete arthrodial joint. It is very curious that we should find developed in man, as the result of the habitual performance of certain movements, a condition of the wrist-joint which closely resembles that which is normal in a large number of the quadrumana, in whom the factors determining its characters are equally obvious.

There exist other tendencies to change in the wrist-joint, on account of the extreme adduction of the hand, namely, to the prolongation downwards of the inner articular surface of the cuneiform bone till it reaches the margin of the metacarpal facet, and even to the apposition of the cuneiform bone to the base of the fifth metacarpal; also, to an increase in the areas of the facets upon the upper angle of the cuneiform bone and the under surface of the semilunar bone. The vacuum which must exist between the upper row of the carpus and the lower surface of the radius, interarticular fibro-cartilage and styloid process, in consequence of the forcible separation of these surfaces, which is due to the great resistance offered by the leather to the passage of the threads through it, must tend to the development of interarticular, synovial, or fibrous fringes of varying density from the inner surface of the ligaments surrounding this articulation, as well as to an increase in the strength and thickness of those ligaments, and to a hypertrophy of those particular bands or layers of fibres which limit excessive adduction of the hand.

While the string is grasped in the left hand during the progress of the sudden and continuing strain exerted upon it, the thumb is retained in forcible apposition to the index finger by the powerful contraction of the flexor longus pollicis and of the several small adductor muscles of the thumb. The strain exerted upon the tendon of the long flexor of the thumb by its muscle brings the opposing articular surfaces of the bones of that digit into very forcible apposition. It tends to produce a forward displacement of the base of the first phalanx from the head of the first metacarpal bone, and, since that joint is partly flexed, to produce very considerable change in the form of the opposing surfaces of metacarpal bone and phalanx, in the form of the lateral ligaments and in the direction of their fibres, and to determine the formation of a synovial fringe in the angular interval which exists between the two bones posteriorly.

Since the carpo-metacarpal articulation is slightly flexed, the strain exerted by the flexor longus pollicis tends to the destruction of the anterior portions of the opposing articular surfaces, to the formation of an interval between their posterior portions, to the development of a synovial fringe or fibro-cartilage to occupy the interval, and to the hypertrophy of the posterior carpo-metacarpal ligament. The same violent apposition of the opposing surfaces of the base of the over-extended second phalanx and the head of the first phalanx tends to produce very definite accommodation changes in their form, as well as an alteration in the length and strength of the ligaments which oppose over-extension.

There exists a tendency to the stretching of the vaginal sheath covering the anterior surface of the first phalanx, and to the displacement forwards of the tendon of the flexor longus pollicis from the anterior aspect of the upper portion of the bone. In this shoemaker the presence of this tendency has resulted in a very remarkable modification of the structure of the vaginal sheath. The very powerful oblique band of fibres represented in fig. 12, apparently originating in one of the limbs of the ligamentum cruciatum, which formed the structure whose function it was to oppose and limit the tendency to displacement of the tendon, was attached below to the anterior interphalangeal ligament, and indirectly through it to the anterior margin of the base of the terminal phalanx. Therefore, when the terminal phalanx was over-extended upon the proximal, the oblique band was rendered extremely tense.

The changes in the right thumb were very similar to those in the left, the differences which were present being dependent upon the fact that the awl was held in the right hand and the string alone in the left.

We seem to learn from the consideration of the anatomy of this workman, that we cannot observe and define too accurately the various modifications in form which the normal bones undergo under the influence of the groups of movements which compose some of the more routine forms of labour, because they represent the fixation and the subsequent exaggeration upon the bone of the results or the tendencies produced by one single movement, in the same manner that the total labour changes in the trunk indicate in a similar manner, first the fixation, and subsequently the exaggeration of the attitude which is assumed during a single performance of the movement or series of movements habitually performed in that particular labour.

Also, because the tendency to produce change in the form of a bone may not be exerted sufficiently long or sufficiently often to produce the change in the parents, or it may, from some peculiarity in the form of the bone, be unable to result in it in either of the parents; yet the influence of that tendency, when it acts as a hereditary factor, may be sufficient to produce or determine the presence of the change in the offspring. That this must take place to a great extent in labourers is, I think, obvious from the consideration of preceding contributions to this *Journal*[1] and to the *Transactions of the Obstetrical Society*, 1887.[2]

EXPLANATION OF PLATE XIX.

Fig. 1 represents the anterior aspect of the atlas, with the prolongation upwards from its anterior arch, and the large quadrilateral mass of bone upon the upper surface of the left lateral mass.

Fig. 2 represents the foramen magnum and condyles of the occipital bone. B, the groove which received the sharp free upper margin of the articular facet upon the atlas; A, the transverse ligament which lay behind the upward prolongation of the odontoid process; C, the facet on the jugular process of the occipital bone, which articulated with the mass of bone projecting upwards from the lateral mass of the atlas.

Fig. 3 represents the axis and third cervical vertebra, the prolongation upwards of the odontoid process with its articular facet, the formation of a layer of bone connecting the arches of the axis and third cervical vertebra, and the seat of the ankylosed articulation of the articular processes.

Fig. 4 represents the upper surface of the right clavicle of the shoemaker. The upper margin of the acromial facet is indicated upon its outer extremity.

Fig. 5 represents the anterior surface of the same bone.

Fig. 6 represents a vertical transverse section through the right sterno-clavicular articulation of an old sailor.

Fig. 7 represents the posterior aspect of the right scapula of the shoemaker, and fig. 8 its vertebral margin. The dotted line in fig. 8 indicates the outline of that portion of the venter of the scapula which corresponds to the floor of the supraspinous fossa.

Figs. 9 and 10 represent respectively the posterior surface and the inner margin of a scapula of a labourer who carried habitually loads on his right shoulder.

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[1] "Can the Existence of a Tendency to Change in the Form of the Skeleton of the Parent result in the Actuality of that Change in the Offspring?" 1888.

[2] "What are the Chief Factors that Determine the Variations which exist in the Form of the Male and Female Pelvis?"

I have represented in fig. 11 the posterior surface of the upper extremity of the left humerus. A points to a portion of the original head which had become functionless; B to the acquired articular surface; and C to an atrophic patch, all of which have been described in this paper.

Fig. 12 represents the trapezium, metacarpal bone, and phalanges of the thumb of the shoemaker.

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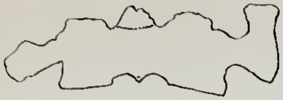
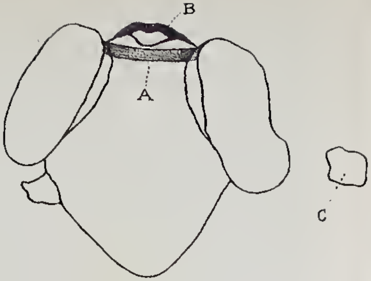


Fig. 1.



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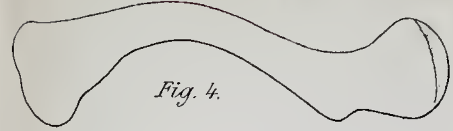

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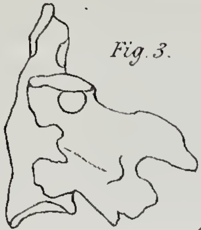

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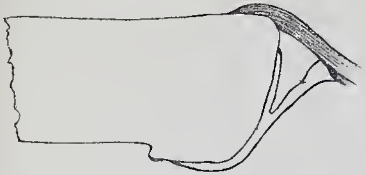

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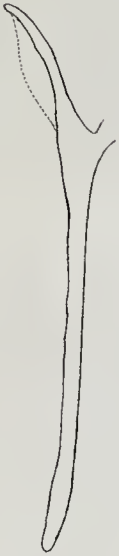

Fig. 8.

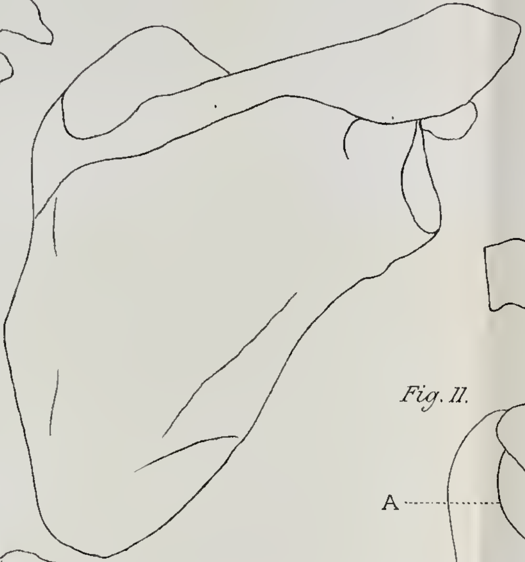

Fig. 7.

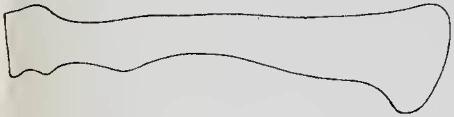

Fig. 5.

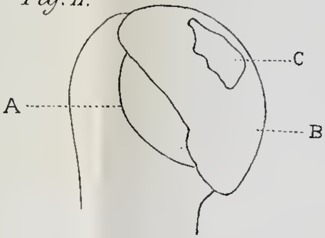

Fig. 11.

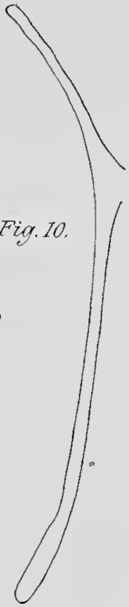

Fig. 10.

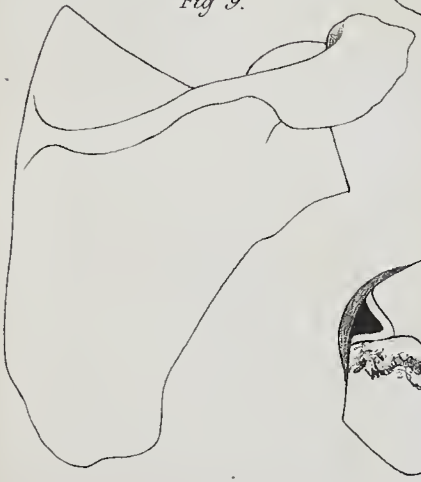

Fig 9.

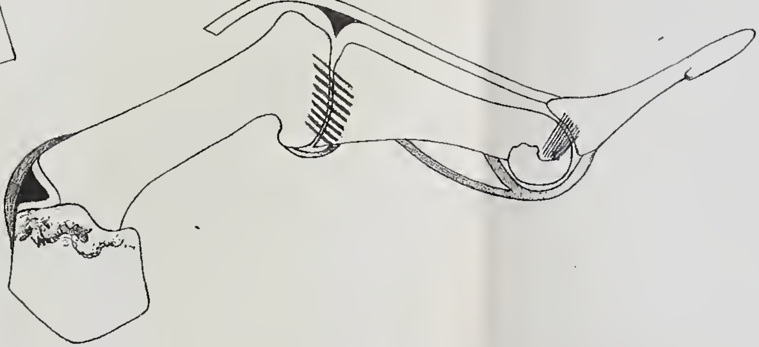

Fig. 12.

BONES OF SHOEMAKER.

F. Huth, Lith.r Edin.r